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Reply to Comments on "Unsaturated soils: From constitutive modelling to numerical algorithms" by Daichao Sheng, Antonio Gens, Delwyn G. Fredlund and Scott W. Sloan [Computers and Geotechnics 35(6) (2008) 810–824] by Jingshuang Li, Yichuan Xing and Yujing Hou

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We would like to thank the discussers for their interest in our paper. The hysteretic soil-water characteristic curve (SWCC) used in the SFG model follows that of [1]. In this model, the SWCC is assumed to be independent of soil density, which represents a simplification of real soil behaviour. Based on this assumption, the relationship between the volumetric water content (θ), suction (s) and volumetric strain (ε_v) follows:

$$\mathrm{d}\theta = \mathrm{d}(nS_r) = n\mathrm{d}S_r + S_r\mathrm{d}n = -\lambda_{ws} n\frac{\mathrm{d}s}{s} + S_r\mathrm{d}\left(\frac{V_v}{V}\right) = -\lambda_{ws} n\frac{\mathrm{d}s}{s} + S_r(1-n)\mathrm{d}\varepsilon_v. \quad (1)$$

There is a misprint in Eq. (36) in [2] and in Eq. (B7) in [3], with $(1-n)$ missing in the second term on the right-hand side. In the equation above the change of soil volume ($\mathrm{d}V$) is assumed to be the same as the change of void volume ($\mathrm{d}V_v$), which is commonly adopted in soil mechanics.

The whole discussion seems to be based on this misprint. The comment that the SFG model overestimates the influence of the volumetric strain on the water content is not valid for the corrected equation, because $S_r(1-n) = S_r - \theta$ can be smaller than θ. Eqs. (2) and (6) in the discussion are not correct and are not used in the SFG model.

A more serious assumption in the equation above is the independence of the SWCC curves on the soil void volume. In real soil behaviour, the SWCC will depend on the soil density or the void ratio, which means the S_r–s relationship will depend on the current void ratio. In this case, the first term on the right-hand side in the equation above will no longer be valid. Instead, it should take the form

$$n\mathrm{d}S_r = A\mathrm{d}s + B\mathrm{d}\varepsilon_v. \quad (2)$$

where the parameters A and B depend on the coupling between SWCC and void ratio. Therefore, the $\theta - s - \varepsilon_v$ relationship takes the form

$$\mathrm{d}\theta = A\mathrm{d}s + (S_r(1-n) + B)\mathrm{d}\varepsilon_v. \quad (3)$$

That said, the simplified model, i.e. Eq. (1), has a number of advantages. For example, it has fewer material parameters. The suction-increase (SI) and suction-decrease (SD) yield surfaces also become horizontal lines in the mean stress–suction space (see Fig. 11 in [2]). In addition, the dependence of the SWCC on soil density is a second order issue, compared to the SWCC itself. Nevertheless, it is one of the possible refinements to the SFG model (see the recent discussion in [4,5]).

There is another misprint in Eq. (35) in [2] or Eq. (B6) in [3]. The correct one should read

$$\mathrm{d}\bar{\boldsymbol{\sigma}} = \mathbf{D}^e\mathrm{d}\boldsymbol{\varepsilon} - \frac{\mathbf{D}^e\frac{\partial g}{\partial \bar{\boldsymbol{\sigma}}}\left(\frac{\partial f}{\partial \bar{\boldsymbol{\sigma}}}\right)^{\mathrm{T}}\mathbf{D}^e\mathrm{d}\boldsymbol{\varepsilon} + \mathbf{D}^e\frac{\partial g}{\partial \bar{\boldsymbol{\sigma}}}\left(\frac{\partial f}{\partial \bar{p}_0}\frac{\partial \bar{p}_0}{\partial s} + \frac{\partial f}{\partial \bar{p}_c}\frac{\partial \bar{p}_c}{\partial s} - \left(\frac{\partial f}{\partial \bar{\boldsymbol{\sigma}}}\right)^{\mathrm{T}}\mathbf{W}^e\right)\mathrm{d}s}{\left(\frac{\partial f}{\partial \bar{\boldsymbol{\sigma}}}\right)^{\mathrm{T}}\mathbf{D}^e\frac{\partial g}{\partial \bar{\boldsymbol{\sigma}}} - \frac{\partial f}{\partial \bar{p}_c}\frac{\partial \bar{p}_c}{\partial \varepsilon_v^p}\frac{\partial g}{\partial \bar{p}}} - \mathbf{W}^e\mathrm{d}s$$

Other equations in Section 4.1 in [2] or in Appendix B in [3] should be modified accordingly.

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